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LISTS OF SPECIES

Insect galls of the Parque Nacional das Emas (Mineiros, GO, Brazil)

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ABSTRACT: In this study we perform an inventory of the insect leaf galls of the Parque Nacional das Emas, Goiás State, Brazil. We found 97 gall morphotypes, distributed on 24 botanical families comprising 37 genera and 55 species. The plant taxa that showed the greatest richness of galls were the families Myrtaceae, with 17 morphotypes and Fabaceae with 14, and the genera *Myrcia* (Myrtaceae) and *Qualea* (Vochysiaceae) with 10 and eight morphotypes, respectively. The plant species *Andira cujabensis* Benth. (Fabaceae) and *Myrcia guianensis* (Aubl.) DC., with four morphotypes each, were the most diverse. We found galling insects belonging to Diptera, Hemiptera and Lepidoptera. The galling insects of family Cecidomyiidae (Diptera) were the most common inducing 38.1% of the gall morphotypes. All recorded gall morphotypes are first records to Parque Nacional das Emas. Among the 55 host plant species listed in the survey, 16 species (20%) have the first report of hosting galls.

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INTRODUCTION

Insect galls can be defined as modifications in the vegetal tissues by hypertrophy and hyperplasia of cells caused by galling insect presence (Shorthouse and Rohfritsch 1992). Although galling insects are globally well distributed, several studies have showed that the Neotropical region is one of the most diverse in galling insect species (Gagné 1994; Espírito-Santo and Fernandes 2007; Carneiro *et al.* 2009). Much of this high diversity in the Neotropic is due to the high complexity of xeric physiognomies of Cerrado Biogeographic Region, a hotspot of galling diversity (Araújo *et al.* 2014).

In this paper, we perform an inventory of the insect leaf galls of Parque Nacional das Emas (PARNA-EMAS) located in Mineiros, Goiás State, Midwest Region of Brazil. The PARNA-EMAS is one of the largest and most important reserves in the Cerrado region with 132,941 ha. Its importance for the conservation of the fauna and flora of the Cerrado has been recognized by UNESCO in 2001 which declared the park as a World Heritage. The park exhibits almost all types of vegetation occurring in the Cerrado region (França *et al.* 2007). Floristic studies record the occurrence of 601 species and 80 families of vascular plants, being Fabaceae, Myrtaceae and Malpighiaceae the most important plant families in the woody vegetations of PARNA-EMAS (Batalha and Martins 2007).

MATERIALS AND METHODS

The study was realized in the xeric vegetations of the PARNA-EMAS (17°49′ – 18°28′ S and 52°39′ – 53°10′ W). The vegetations sampled were constituted by fields and savannas (Cerrado *sensu stricto*). The field vegetations cover 68.1% of the total area, whereas Cerrado *sensu stricto* covers 25.1% of the reserve. The climate of regions is classified as Aw of Köppen or humid tropical with wet summer and dry winter. The most of park consist of flat tableland, at an altitude of 820-888 m, and the remaining area consists of hilly terrain, at an altitude of 720–820 m (Ramos-Neto and Pivello 2000).

The sampling in the different phytophysiognomies was done in November 2013 through plots of 10 × 10m, where only woody plants with a diameter above 3 cm at ground level were included. Altogether 49 plots were established, being 39 in field vegetation and 10 in savanna vegetation. In each plot, all included plants had 10 leaves randomly inspected and all galls founds were registered. Samples of each gall morphotypes were photographed, collected and transported individually in labeled plastic bags.

All woody plant species sampled in the plots were determined and identified with metal platelets in studies previously realized in the area. Galls were classified in morphotypes using the host plant species and the external morphology (leaf part, form, color, pubescence, and size). The insect obtainment was done by dissecting of galls in field or laboratory. Galling identification was realized across of examination of immature insects and consult to literature of gall morphotypes registered from Brazil and Cerrado (*e.g.,* Gagné 1994; Maia and Fernandes 2004; Araújo *et al.* 2011).

RESULTS

We found 97 gall morphotypes, distributed on 24 botanical families comprising 37 genera and 55 species (Table 1; Figures 1–3). The plant families that showed the greatest richness of galls were Myrtaceae with 17 morphotypes, Fabaceae with 14 morphotypes, Vochysiaceae with nine morphotypes, Malpighiaceae and Malvaceae with six morphotypes each one. The remaining families were registered with four to one gall morphotypes (Table 1).

The plant genera most diverse in galls were *Myrcia*

Table 1. Number of host plant species and insect gall morphotypes in the host plant families recorded in the Parque Nacional das Emas in Mineiros, GO, Brazil.

HOST FAMILY	NUMBER OF PLANT SPECIES	NUMBER OF PLANT GENERA	NUMBER OF GALL MORPHOTYPES
Annonaceae	2	2	3
Apocynaceae	2	1	2
Araliaceae	1	1	2
Asteraceae	2	2	3
Bignoniaceae	1	1	1
Calophyllaceae	2	1	4
Caryocaraceae	1	1	3
Chrysobalanaceae	1	1	1
Connaraceae	2	2	3
Dilleniaceae	1	1	1
Ebenaceae	1	1	3
Erythroxylaceae	2	1	2
Fabaceae	8	7	14
Malpighiaceae	3	1	6
Malvaceae	2	1	6
Melastomataceae	1	1	2
Myrtaceae	11	4	17
Nyctaginaceae	1	1	3
Ochnaceae	2	1	3
Proteaceae	1	1	3
Rubiaceae	1	1	1
Salicaceae	1	1	1
Sapotaceae	2	1	4
Vochysiaceae	4	2	9
Total	55	37	97

(Myrtaceae), *Qualea* (Vochysiaceae) and *Byrsonima* (Malpighiaceae), with 10, eight and six morphotypes, respectively (Table 2). The plant species *Andira cujabensis* Benth. (Fabaceae) and *Myrcia guianensis* (Aubl.) DC, with four morphotypes each, were the most diverse. Others 12 plant species hosted three gall morphotypes, 12 plant species hosted two morphotypes and 21 plant species hosted only one morphotype (Table 2).

In this study we found galling insects belonging to Diptera, Hemiptera and Lepidoptera (Table 3). The galling insects of family Cecidomyiidae (Diptera) were the most common inducing 38.1% of the gall morphotypes. Galling of Lepidoptera and Hemiptera were found in 5.2% and 2.0% of the morphotypes, respectively. In 54.6% of the gall morphotypes we did not find the gall-inducing insects.

All recorded gall morphotypes are first records to PARNA-EMAS. Among the 55 host plant species listed in the survey, 16 species (20%) have the first report of hosting galls: *A. cujabensis* Benth, *Aspidosperma nobile* Müll.Arg., *Bocageopsis mattogrossensis* (R.E.Fr.) R.E.Fr., *Campomanesia adamantium* (Cambess.) O.Berg, *Casearia sylvestris* Sw., *Eugenia ternatifolia* Cambess, *Erythroxylum engleri* O.E.Schulz, *Licania humilis* Cham. & Schltdl., *Myrcia bella* Cambess, *Myrcia camapuanensis* N. Silveira, *M. guianensis* (Aubl.) DC., *Myrcia variabilis* DC,

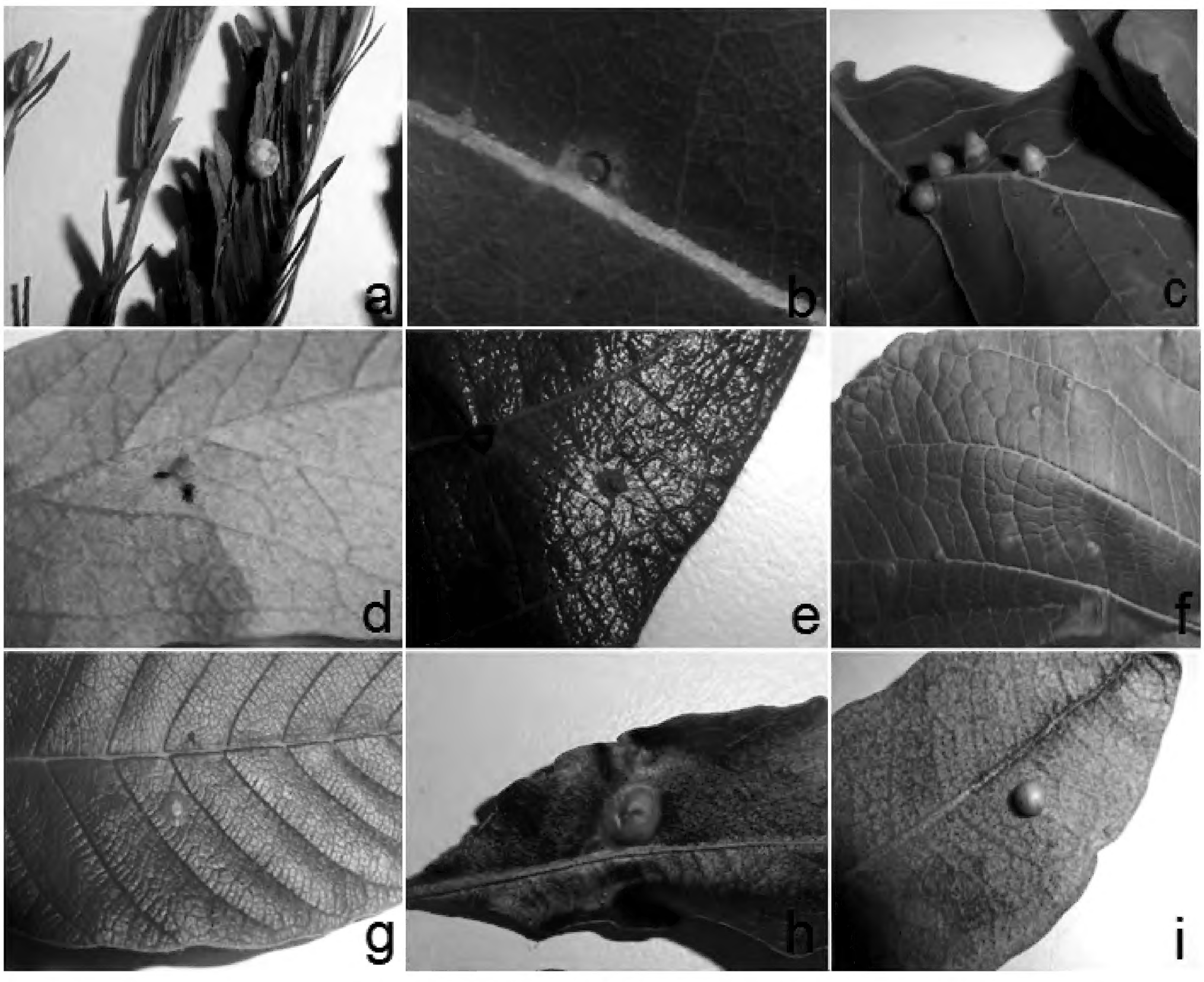

Figure 1. Example of insect galls recorded in the Parque Nacional das Emas in Mineiros, GO, Brazil: a) Globoid leaf gall on *Anadenanthera falcata*; b) Discoid leaf gall on *Bowdichia virgilioides*; c) Conical leaf galls on *Byrsonima coccolobifolia*; d) Conical leaf gall on *Byrsonima pachyphylla*; e) Discoid leaf gall on *Byrsonima verbascifolia*; f) Discoid leaf galls on *Caryocar brasiliense*; g) Discoid leaf gall on *Davilla elliptica*; h) Globoid leaf gall on *Eremanthus erythropappus*; i) Globoid leaf gall on *Eriotheca pubescens*.

Table 2. Host plants (family and species) and insect gall morphotypes recorded in the Parque Nacional das Emas in Mineiros, GO, Brazil.

HOST FAMILY	INSECT GALLS				
HOST SPECIES	**ORGAN**	**FORM**	**COLOR**	**PUBESCENCE**	**GALLING INSECT**
Annonaceae					
Annona coriacea Mart.	Leaf lamina	Discoid	Yellow	Glabrous	Cecidomyiidae
	Midvein	Ellipsoid	Brown	Glabrous	Cecidomyiidae
Bocageopsis mattogrossensis (R.E.Fr.) R.E.Fr.	Leaf lamina	Discoid	Yellow	Glabrous	Indeterminate
Apocynaceae					
Aspidosperma macrocarpon Mart.	Leaf lamina	Conical	Green	Pubescent	Indeterminate
Aspidosperma nobile Müll.Arg.	Leaf lamina	Discoid	Green	Glabrous	Indeterminate
Araliaceae					
Schefflera vinosa (Cham. & Schltdl.) Frodin & Fiaschi	Midvein	Ellipsoid	Brown	Glabrous	Lepidoptera
	Petiole	Ellipsoid	Brown	Glabrous	Lepidoptera
Asteraceae					
Eremanthus erythropappus (DC.) MacLeish	Leaf lamina	Globoid	Green	Pubescent	Cecidomyiidae
Piptocarpha rotundifolia (Less.) Baker	Leaf lamina	Discoid	Green	Glabrous	Indeterminate
	Midvein	Ellipsoid	Green	Pubescent	Indeterminate
Bignoniaceae					
Handroanthus ochraceus (Cham.) Mattos	Leaf lamina	Conical	Brown	Pubescent	Indeterminate
Calophyllaceae					
Kielmeyera coriacea Mart. & Zucc.	Leaf lamina	Globoid	Brown	Glabrous	Indeterminate
	Midvein	Ellipsoid	Brown	Glabrous	Indeterminate
	Midvein	Amorphous	Brown	Glabrous	Indeterminate
Kielmeyera grandiflora (Wawra) Saddi	Leaf lamina	Discoid	Brown	Glabrous	Indeterminate
Caryocaraceae					
Caryocar brasiliense Cambess.	Leaf lamina	Discoid	Yellow	Pubescent	Cecidomyiidae
	Leaf lamina	Globoid	Yellow	Pubescent	Cecidomyiidae
	Petiole	Globoid	Brown	Pubescent	Cecidomyiidae
Chrysobalanaceae					
Licania humilis Cham. & Schltdl.	Midvein	Globoid	Brown	Glabrous	Indeterminate
Connaraceae					
Connarus suberosus Planch.	Leaf lamina	Discoid	Green	Glabrous	Cecidomyiidae
	Midvein	Ellipsoid	Brown	Glabrous	Cecidomyiidae
Rourea induta Planch.	Leaf lamina	Discoid	Green	Glabrous	Indeterminate
Dilleniaceae					
Davilla elliptica A.St.-Hil.	Leaf lamina	Discoid	Green	Pubescent	Cecidomyiidae
Ebenaceae					
Diospyros hispida A.DC.	Leaf lamina	Discoid	Yellow	Pubescent	Indeterminate
	Leaf lamina	Discoid	Yellow	Glabrous	Indeterminate
	Leaf lamina	Globoid	Yellow	Pubescent	Indeterminate
Erythroxylaceae					
Erythroxylum engleri O.E.Schulz	Leaf lamina	Discoid	Yellow	Glabrous	Indeterminate
Erythroxylum suberosum A.St.-Hil.	Leaf lamina	Marginal leaf roll	Green	Glabrous	Cecidomyiidae
Fabaceae					
Anadenanthera falcata (Benth.) Speg.	Leaf lamina	Globoid	Red	Glabrous	Cecidomyiidae
Andira cujabensis Benth.	Leaf lamina	Discoid	Green	Glabrous	Cecidomyiidae
	Leaf lamina	Conical	Green	Pubescent	Cecidomyiidae
	Midvein	Ellipsoid	Brown	Glabrous	Cecidomyiidae
	Petiole	Globoid	Brown	Pubescent	Cecidomyiidae
Bowdichia virgilioides Kunth	Leaf lamina	Discoid	Green	Glabrous	Indeterminate
	Midvein	Ellipsoid	Green	Pubescent	Indeterminate
Hymenaea stigonocarpa Mart. ex Hayne	Leaf lamina	Discoid	Yellow	Pubescent	Cecidomyiidae
Leotolobium dasycarpum Vogel	Leaf lamina	Discoid	Green	Glabrous	Cecidomyiidae
	Midvein	Ellipsoid	Green	Glabrous	Cecidomyiidae
Stryphnodendron adstringens (Mart.) Coville	Leaf lamina	Discoid	Brown	Glabrous	Indeterminate
	Midvein	Ellipsoid	Brown	Glabrous	Indeterminate
Tachigali aurea Tul.	Leaf lamina	Ellipsoid	Brown	Glabrous	Lepidoptera
Tachigali vulgaris L.G.Silva & H.C.Lima	Leaf lamina	Globoid	Yellow	Glabrous	Indeterminate
Malpighiaceae					
Byrsonima coccolobifolia Kunth	Leaf lamina	Conical	Green	Glabrous	Cecidomyiidae
	Leaf lamina	Discoid	Yellow	Glabrous	Indeterminate
	Leaf lamina	Discoid	Brown	Rough	Indeterminate
Byrsonima pachyphylla A.Juss.	Leaf lamina	Conical	Brown	Pubescent	Cecidomyiidae
	Leaf lamina	Discoid	Green	Glabrous	Indeterminate
Byrsonima verbascifolia (L.) DC.	Leaf lamina	Discoid	Green	Pubescent	Indeterminate

Table 2. *Continued.*

HOST FAMILY	INSECT GALLS				
HOST SPECIES	**ORGAN**	**FORM**	**COLOR**	**PUBESCENCE**	**GALLING INSECT**
Malvaceae					
Eriotheca gracilipes (K.Schum.) A.Robyns	Leaf lamina	Discoid	Green	Glabrous	Indeterminate
	Midvein	Ellipsoid	Green	Glabrous	Indeterminate
	Midvein	Globoid	Brown	Glabrous	Indeterminate
Eriotheca pubescens (Mart. & Zucc.) Schott & Endl.	Leaf lamina	Globoid	Brown	Pubescent	Cecidomyiidae
	Leaf lamina	Discoid	Brown	Glabrous	Indeterminate
	Leaf lamina	Globoid	Brown	Glabrous	Indeterminate
Melastomataceae					
Miconia albicans (Sw.) Triana	Leaf lamina	Globoid	Brown	Rough	Cecidomyiidae
	Leaf lamina	Discoid	Brown	Glabrous	Cecidomyiidae
Myrtaceae					
Campomanesia adamantium (Cambess.) O.Berg	Leaf lamina	Discoid	Brown	Glabrous	Indeterminate
Eugenia aurata O.Berg	Leaf lamina	Discoid	Black	Glabrous	Indeterminate
Eugenia sp.	Leaf lamina	Discoid	Green	Glabrous	Indeterminate
Eugenia ternatifolia Cambess.	Leaf lamina	Globoid	Green	Pubescent	Cecidomyiidae
Myrcia bella Cambess.	Leaf lamina	Discoid	Brown	Glabrous	Indeterminate
	Midvein	Ellipsoid	Green	Pubescent	Indeterminate
Myrcia camapuanensis N.Silveira	Midvein	Globoid	Brown	Pubescent	Indeterminate
Myrcia guianensis (Aubl.) DC.	Leaf lamina	Globoid	Green	Pubescent	Indeterminate
	Leaf lamina	Discoid	Green	Glabrous	Indeterminate
	Midvein	Globoid	Brown	Pubescent	Indeterminate
	Midvein	Conical	Green	Pubescent	Indeterminate
Myrcia multiflora (Lam.) DC.	Leaf lamina	Globoid	Green	Glabrous	Indeterminate
Myrcia variabilis DC.	Leaf lamina	Discoid	Brown	Glabrous	Indeterminate
Myrcia vestita DC.	Leaf lamina	Discoid	Yellow	Glabrous	Indeterminate
Psidium laruotteanum Cambess.	Leaf lamina	Globoid	Brown	Glabrous	Psyllidae
	Leaf lamina	Discoid	Brown	Pubescent	Indeterminate
	Leaf lamina	Marginal leaf roll	Green	Glabrous	Indeterminate
Nyctaginaceae					
Guapira noxia (Netto) Lundell	Leaf lamina	Discoid	Brown	Glabrous	Indeterminate
	Midvein	Ellipsoid	Brown	Pubescent	Indeterminate
	Midvein	Globoid	Brown	Glabrous	Indeterminate
Ochnaceae					
Ouratea hexasperma (A.St.-Hil.) Baill.	Leaf lamina	Discoid	Green	Glabrous	Cecidomyiidae
Ouratea spectabilis (Mart.) Engl.	Leaf lamina	Discoid	Green	Glabrous	Cecidomyiidae
	Leaf lamina	Conical	Brown	Glabrous	Cecidomyiidae
Proteaceae					
Roupala montana Aubl.	Leaf lamina	Discoid	Green	Pubescent	Cecidomyiidae
	Midvein	Ellipsoid	Green	Pubescent	Lepidoptera
	Petiole	Ellipsoid	Red	Pubescent	Lepidoptera
Rubiaceae					
Palicourea rigida Kunth	Leaf lamina	Globoid	Brown	Glabrous	Cecidomyiidae
Salicaceae					
Casearia sylvestris Sw.	Leaf lamina	Discoid	Brown	Glabrous	Indeterminate
Sapotaceae					
Pouteria ramiflora (Mart.) Radlk.	Leaf lamina	Discoid	Brown	Glabrous	Indeterminate
Pouteria torta (Mart.) Radlk.	Leaf lamina	Conical	Green	Pubescent	Hemiptera
	Leaf lamina	Discoid	Yellow	Glabrous	Indeterminate
	Leaf lamina	Conical	Brown	Pubescent	Indeterminate
Vochysiaceae					
Qualea grandiflora Mart.	Leaf lamina	Discoid	Green	Glabrous	Cecidomyiidae
	Leaf lamina	Globoid	Green	Glabrous	Cecidomyiidae
	Leaf lamina	Conical	Green	Glabrous	Cecidomyiidae
Qualea multiflora Mart.	Leaf lamina	Discoid	Green	Glabrous	Cecidomyiidae
	Midvein	Ellipsoid	Brown	Glabrous	Cecidomyiidae
Qualea parviflora Mart.	Leaf lamina	Conical	Green	Glabrous	Cecidomyiidae
	Leaf lamina	Star	Green	Rough	Cecidomyiidae
	Leaf lamina	Discoid	Green	Glabrous	Cecidomyiidae
Vochysia sp.	Leaf lamina	Discoid	Green	Glabrous	Indeterminate

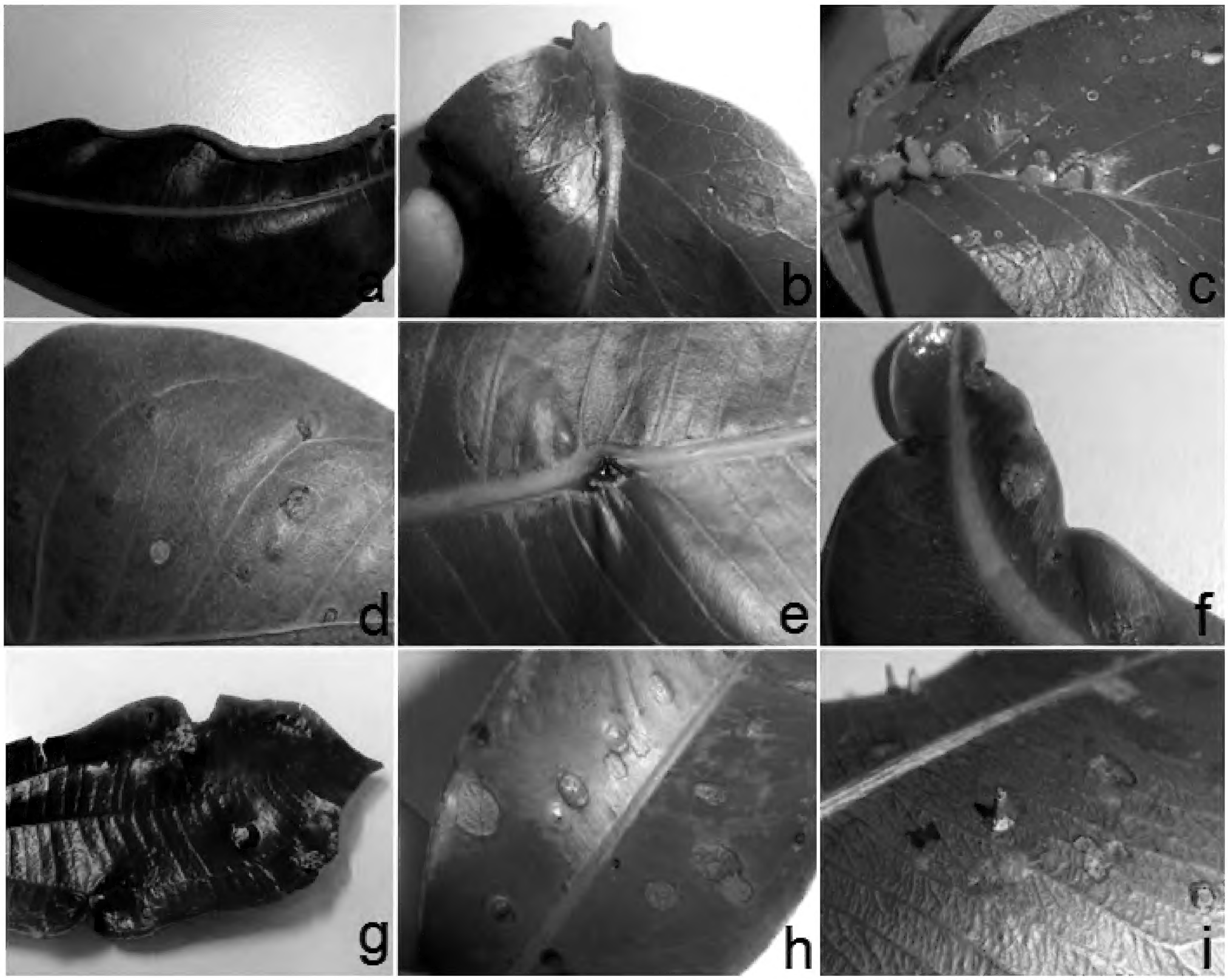

Figure 2. Example of insect galls recorded in the Parque Nacional das Emas in Mineiros, GO, Brazil: a) Marginal leaf roll on *Erythroxylum suberosum*; b) Globoid galls in midvein of *Guapira noxia*; c) Conical leaf galls on *Handroanthus ochraceus*; d) Discoid leaf galls on *Hymenaea stigonocarpa*; e) Ellipsoid gall in midvein of *Kielmeyera coriacea*; f) Discoid leaf galls on *Kielmeyera grandiflora*; g) Globoid leaf galls on *Miconia albicans*; h) Discoid leaf galls on *Ouratea hexasperma*; i) Conical leaf galls on *Ouratea spectabilis*.

Myrcia vestita DC, *Rourea induta* Planch., *Schefflera vinosa* (Cham. & Schltdl.) Frodin & Fiaschi and *Tachigali aurea* Tul. These plant species hosted 24 gall morphotypes, representing 27% of total.

Table 3. Number and percentage of gall morphotypes in the different taxa of galling insects recorded in the Parque Nacional das Emas in Mineiros, GO, Brazil.

GALLING INSECT TAXA	GALL MORPHOTYPES	
	N	%
Cecidomyiidae (Diptera)	37	38.2
Lepidoptera	5	5.2
Hemiptera	1	1.0
Psyllidae (Hemiptera)	1	1.0
Indeterminate	53	54.6
Total	97	100

Discussion

We recorded 97 gall morphotypes in PARNA-EMAS, which is relatively high when compared to other similar vegetations. For example, 62 gall morphotypes were recorded in savannas and forests of the Parque Estadual da Serra dos Pireneus (Araújo *et al*. 2011). In others studies were recorded 47 morphotypes in the Parque Estadual da Serra do Cabral (Coelho *et al*. 2013) and 38 gall types in the Parque Estadual Paulo César Vinha (Bregonci *et al*. 2010). These results indicate that PARNA-EMAS have a great diversity of galling insects.

Our main explanation to high gall diversity in the PARNA-EMAS is the dominance of xeric vegetations, which cover most of 90% of the reserve area (Ramos-Neto and Pivello 2000). Comparisons between different types of vegetations have pointed to a higher galling insect richness in the xeric plants (Gonçalves-Alvim and Fernandes 2001; Araújo *et al*. 2011). This differential distribution of galling insects in sclerophyllous vegetation can be due to three ecological mechanisms: plant stress, nutritional robustness and relationships with natural enemies (Araújo *et al*. 2014). Plants in xeric environments are under stress conditions, as water and nutrient scarcity that result in physiological changes and low protein production (Araújo *et al*. 2014). Galling insects have developed the ability to circumvent the toxic and nutritional restrictions of sclerophyllous plants under stress conditions (Wright and Samways 1998). In addition, at xeric environments, galling insects obtains protection from natural enemies, given the low diversity and frequency of parasitoids on harsh abiotic factors (Fleck and Fonseca 2007).

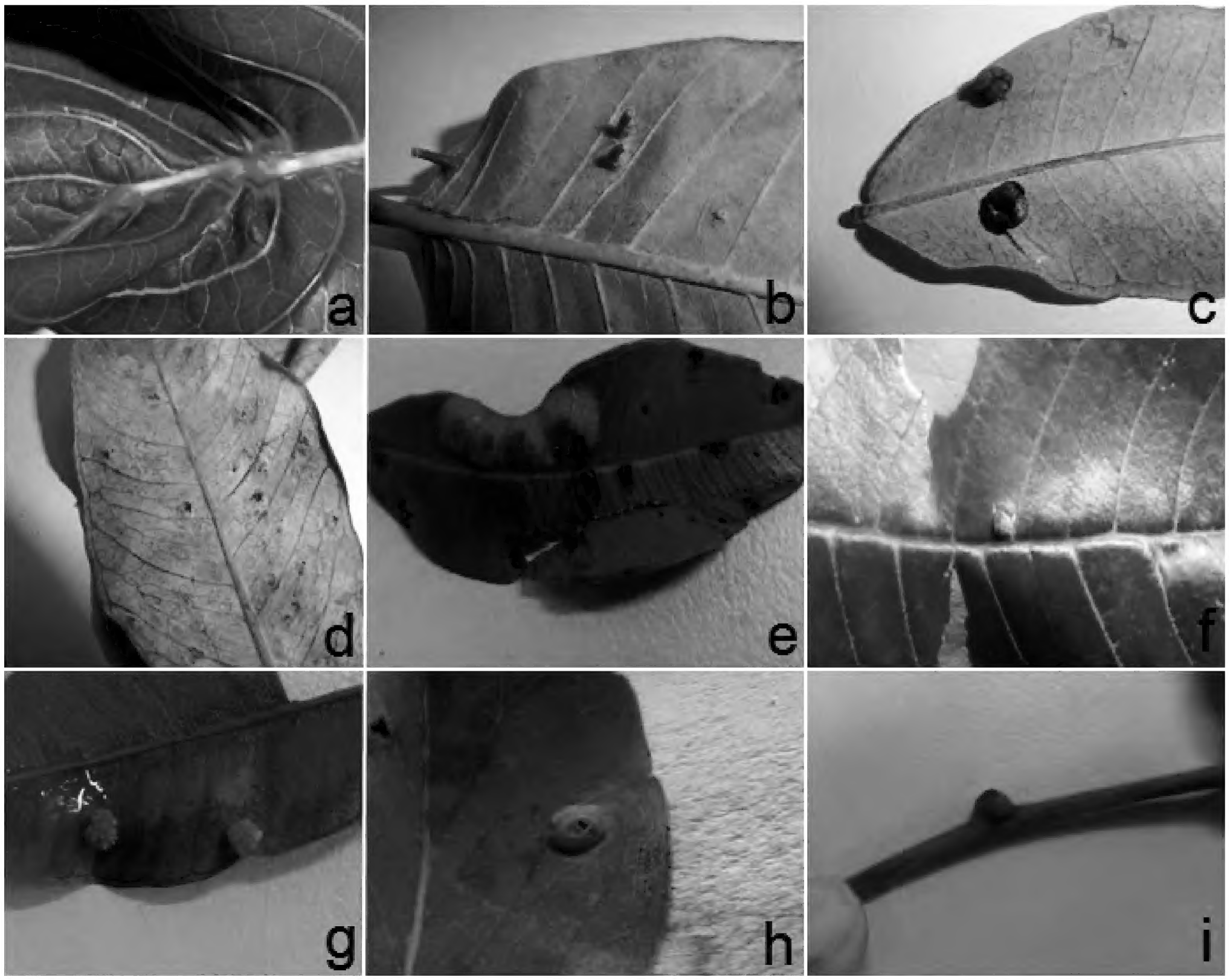

Figure 3. Example of insect galls recorded in the Parque Nacional das Emas in Mineiros, GO, Brazil: a) Globoid leaf galls in midvein of *Palicourea rigida*; b) Conical leaf galls on *Pouteria torta*; c) Globoid leaf galls on *Psidium laruotteanum*; d) Discoid leaf galls on *Qualea grandiflora*; e) Discoid leaf galls on *Qualea multiflora*; f) Discoid leaf galls on *Qualea parviflora*; g) Star leaf galls on *Qualea parviflora*; h) Discoid leaf gall on *Roupala montana*; i) Globoid gall in petiole of *Roupala montana*.

The most diverse host family recorded in our study was Myrtaceae with 17 gall morphotypes. This result is different from most inventories on gall diversity in the Cerrado that indicate that Fabaceae (Gonçalves-Alvim and Fernandes 2001; Maia and Fernandes 2004; Santos *et al*. 2010; Araújo *et al*. 2011) and Asteraceae (Fernandes *et al*. 1996, Carneiro *et al*. 2009) are the most important host families. The high richness of galls in Myrtaceae can be attributed to high local number of host plant species recorded (18% of total). Myrtaceae is among the three most important plant families in the woody vegetations of PARNA-EMAS, together with Fabaceae and Malpighiaceae (Batalha and Martins 2007). We recorded Fabaceae as the second most important host family with 14 gall morphotypes, followed by Vochysiaceae with nine morphotypes. This latter family, have been pointed as an important host of galls in the Cerrado, even with a low diversity of plant species (Araújo *et al*. 2013).

The plant genera with the highest gall diversity in this study were *Myrcia* and *Qualea*, with 10 and eight gall morphotypes, respectively. The genus *Myrcia* was recorded with 10 gall morphotypes in restingas of Bertioga (Maia *et al*. 2008). Araújo *et al*. (2013) recorded 18 galling species on *Qualea* (Vochysiaceae) and eight on *Qualea parviflora* in different Brazilian savannas. About the high gall diversity on the plant species *A. cujabensis* and *M. guianensis,* the most important host species in the present study, there are no reports in the literature.

The galling insects of family Cecidomyiidae were the most important in the fauna studied, representing 84% of the obtained gall-makers. This result corroborate previous studies that pointed the dominance of Cecidomyiidae in the Neotropical savannas (Gonçalves-Alvim and Fernandes 2001; Maia and Fernandes 2004; Santos *et al*. 2010; Araújo *et al*. 2011). According to Araújo *et al*. (2014) the adaptive radiation strongly opportunistic of Cecidomyiidae associated to highly diverse flora are the main responsible by high diversity of group in the Cerrado.

To the best of our knowledge, this is the first systematic survey of insect galls realized in the PARNA-EMAS. The fact that 24% of the plant species listed in this study never have been recorded as gall-hosts demonstrates the need to increase the sampling efforts of insect galls in new areas, mainly areas highly conserved as the studied reserve. We believe that future studies in the park in other months of

year (seasonal inventories) and other vegetation types may be important for understanding their regional galling fauna.

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